Precast Concrete Elements for Accelerated Bridge Construction

tech transfer summary

Using precast concrete elements for accelerated bridge construction can minimze construction time and costs and improve durability.

Objectives

- Evaluate the performance of precast concrete bridge elements in the laboratory and at three sites in Iowa.
- Monitor and evaluate the long-term behavior and overall performance of the three completed bridges that used precast elements.
- Evaluate accelerated construction techniques and develop more efficient methods of bridge construction using precast elements.

Placing a precast concrete abutment cap

Problem Statement

As the U.S. highway infrastructure faces higher traffic volumes and increased structural inadequacies, using precast concrete elements for bridges can minimize traffic disruption during construction, increase durability and useful life, and lower construction and life-cycle costs. In segmental, precast construction, the individual components are manufactured off-site, which usually increases the components' quality; minimizes the amount of disruptive, labor-intensive, on-site work; and reduces construction times.

For these reasons, both the Federal Highway Administration (FHWA) and the Iowa Department of Transportation (Iowa DOT) Office of Bridges and Structures have recognized the importance of using precast concrete elements in bridge construction. Before wide-scale implementation, however, the benefits of precast bridge elements and accelerated construction practices must be verified in the laboratory and field.

In this research, precast bridge elements, accelerated construction practices, and the completed bridges were examined at three sites in Iowa: Boone County, Madison County, and Black Hawk County.

BRIDGE ENGINEERING CENTER

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RESEARCH PROJECT TITLE
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The Bridge Engineering Center (BEC) is part of the Center for Transportation Research and Education (CTRE) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Recommendations

- These projects directly demonstrate the effectiveness of precast structural elements and accelerated construction techniques for constructing new bridges.
- Fabrication of precast elements should begin before on-site construction so progress in the field is not delayed by the fabrication of precast elements.
- The precast superstructure and substructure components that were designed and utilized in the demonstration bridges were shown to exhibit acceptable structural performance through both laboratory and field testing.
- The PMBISB superstructure and substructure systems developed in Black Hawk County can be fabricated and constructed by essentially any county.

Implementation

- The successful implementation of these bridges has far reaching implications in Iowa and nationwide; in many instances, proven rapid construction techniques could result in significant cost reductions.
- More economical and efficient designs should be studied for precast elements and for bridges built using accelerated construction.
- To reduce total construction time, future research should investigate how to replace cast-in-place concrete with precast abutment caps, wingwalls, and barrier rails.

Laboratory testing on a precast abutment cap

Precast abutment cap at Madison County bridge site

Precast pier cap lowered into place at Boone County bridge site

Full-depth precast concrete bridge deck panel used in the Boone County bridge

Boone County

Approach

A continuous four-girder, three-span bridge was constructed on 120th Street in 2006. The bridge included precast abutments and pier cap elements, prestressed beams, and precast full-depth deck panels. Laboratory and field tests were used to investigate the performance of the precast elements, and the completed bridge, which was field tested twice, immediately following construction and one year later.

Findings

- In the laboratory, the pier caps and different pile configurations resisted between two and four times the unfactored design load.
- Laboratory-tested deck panels exceeded the specified strength by 27%, and panel failures occurred at loads much greater than those the panels would experience in the field.
- During laboratory lifting tests, both strap configurations tested were found to be acceptable. During service-level load testing, deck panel strains and stresses were below the AASHTO and ACI limits.
- After post-tensioning, all of the strands were within the tolerances specified by the Iowa DOT. Strains (stresses) measured in the panels were relatively constant throughout the deck.
- During construction, all of the precast elements were set quickly and smoothly with no problems.
- During field testing, the bridge experienced very small displacements and strains.

Completed box girder bridge in Madison County

Fabrication of a precast box girder for the Madison County bridge

Placement of a precast box girder at the Madison County bridge site

Completed bridge over 120th Street, Boone County

Precast abutment and pier cap in place at the Boone County bridge site

Madison County

Approach

A two-lane single-span precast box girder bridge was constructed in 2007 over a stream. The bridge's precast elements included precast cap beams and precast box girders. Precast element fabrication and bridge construction were observed, two precast box girders were tested in the laboratory, and the completed bridge was field tested in 2007 and 2008.

Findings

- In the laboratory, the shear key effectively transfered load to adjacent box girders, and an intact shear key was determined to be critical for good performance.
- Girder cracking occurred at an applied moment greater than the theoretical moment, and cracking did not occur under service-level loads.
- In the laboratory, the applied flexural strength moment exceeded the theoretical moment strength, the experimental shear strength exceeded the theoretical shear strength, and service-level loads did not exceed service limit state stresses.
- For two of four laboratory tests, the guardrail connection exceeded the AASHTO design transverse force. In the other two tests, the surrounding posts had already been tested to failure.
- On the completed bridge, the maximum deflection was less than current code limits and predicted design values.
- Very little differential displacement occurred between longitudinal girder joints.
- For box girder bridge design evaluated in this work, a 0.5 load distribution factor was determined to be conservative and is recommended for this type of bridge.

Black Hawk County

Approach

Two precast modified beam-in-slab bridge (PMBISB) systems were constructed in 2007, one on Mount Vernon Road and one on Marquis Road. Each bridge included precast abutment caps, backwall, and deck panels. In the laboratory, the abutment caps and backwall were tested for behavior and strength, and three panel-to-panel connections were evaluated for strength, cost, and constructability. The bridges were then constructed based on the findings of the panel-to-panel study, and the completed bridges were field tested.

Findings

- In the laboratory, the abutment caps exhibited sufficient positive flexural capacity to meet expected demand. Each cap's positive moment strength exceeded the positive design moment.
- All three panel-to-panel connection types transferred the load across the joint during laboratory testing, but the Type 1 connection was preferred.
- Adding H-piles to the backwall system greatly increased its strength. Despite being prematurely damaged, the backwall provided a factor of safety of 1.6 against failure.
- In the field, stresses induced in both bridges were very low.
- The guardrail contributes a small amount to the flexural resistance of the completed bridge. The abutments provide a small amount of rotational restraint.
- The developed connection for the PMBISB panels effectively transfers load transversely, and the bridges meet AASHTO deflection serviceability criteria.

Using a crane to position a precast deck panel at the Mt. Vernon Road Bridge in Black Hawk County

Completed bridge decks on Marquis Road (top left) and Mt. Vernon Road (bottom left) in Black Hawk County